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ABIACA CREEK SEDIMENTATION STUDY

by

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A numerical sedimentation model study was conducted to determine the effectiveness of the proposed Abiaca Creek sediment reduction scheme under both existing and plan levee conditions. The sediment reduction scheme consisted of controlling the release of sand tailings from gravel mining operations on both Abiaca and Coila Creeks. To perform the analysis, the one-dimensional numerical sedimentation model (TABS-1) was applied with a simulation time of 30 years. The model was not only used to assess the impact of the proposed levee and gravel mining modifications to Abiaca Creek sedimentation, but also to assess change in sand delivery to the Matthews Brake wetlands area under plan conditions.

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PREFACE

The numerical model investigation of Abiaca Creek sedimentation resulting from the proposed levee construction, reported herein, was conducted at the US Army Engineer Waterways Experiment Station (WES) at the request of the US Army Engineer District, Vicksburg (LMK).

This investigation was conducted during the period February to December 1991 by personnel of the Hydraulics Laboratory at WES under the direction of Messrs. Frank A. Herrmann, Jr., Director of the Hydraulics Laboratory; R. A. Sager, Assistant Director of the Hydraulics Laboratory; Marden B. Boyd, Chief of the Waterways Division, Hydraulics Laboratory; and Michael J. Trawle, Chief of the Math Modeling Branch (MMB), Waterways Division. The work was conducted and the report prepared by Mr. Gary E. Freeman, Ms. Lisa W. Benn, Mr. Nolan K. Raphelt, and Mr. William A. Thomas, Math Modeling Branch.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander and Deputy Director was COL Leonard G. Hassell, EN.

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CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASURE

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
cubic feet	0.02831685	cubic metres
feet	0.3048	metres
inches	2.54	centimetres
miles (US statute)	1.609344	kilometres
square miles	2.589998	square kilometres

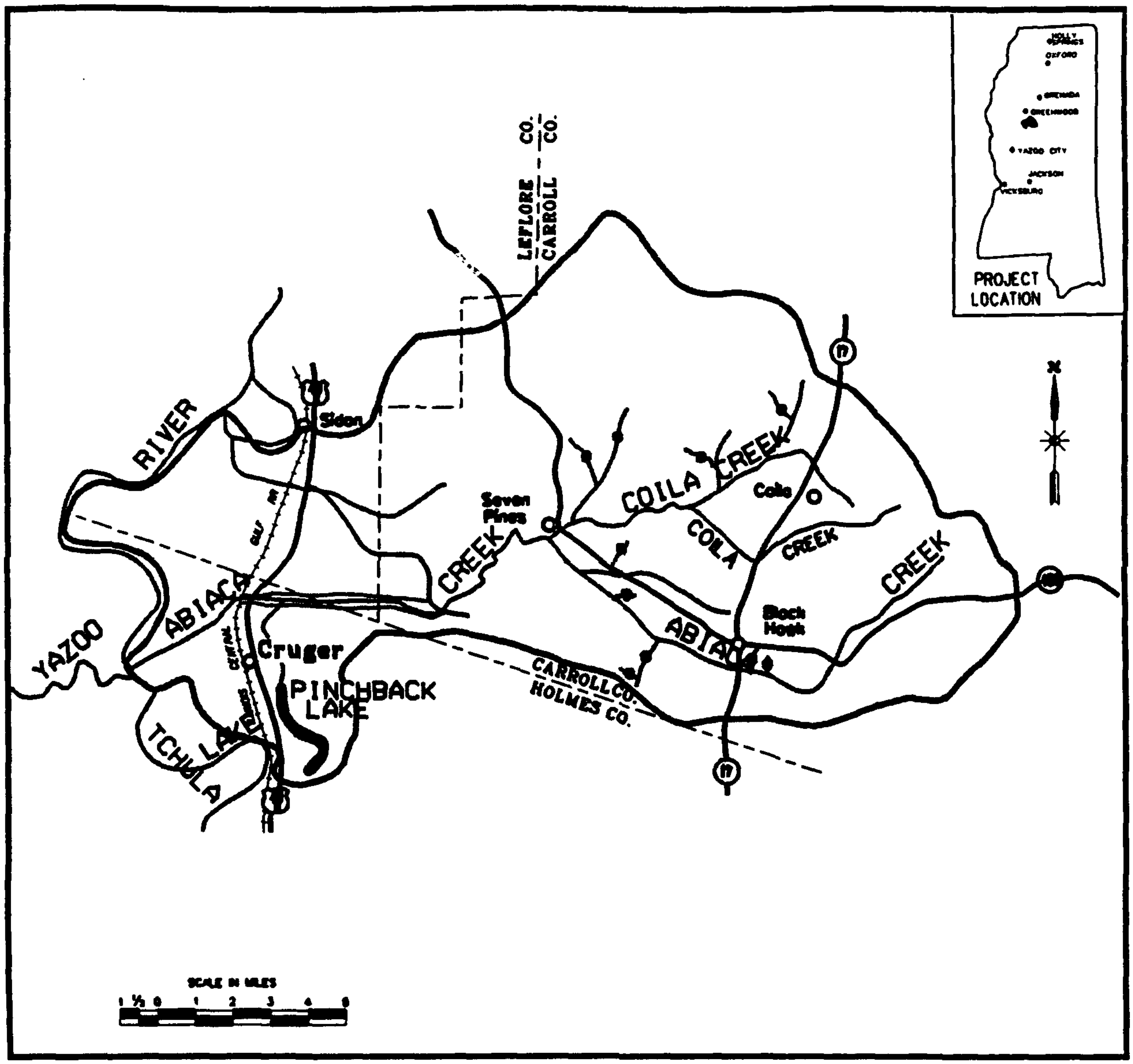


Figure 1. Abiaca Creek watershed

ABIACA CREEK SEDIMENTATION STUDY

Numerical Model Investigation

PART I: INTRODUCTION

Description of the Watershed

1. The Abiaca Creek watershed is an east-bank tributary to the Yazoo River and is located southeast of Greenwood, Mississippi and north/northeast of Yazoo City (Figure 1). The total Abiaca Creek drainage area is approximately 95 square miles and contains the communities of Black Hawk and Coila. Located beyond the bluff line at the eastern edge of the Yazoo Delta, the watershed consists of loessial silts and underlying sands and gravels. It contains rugged hills and ridges adjacent to noticeably flat valleys along the main channels. The hills range from moderate to very steep in slope and are broken by gullies and ravines. The soils in the hilly areas are composed of mainly silts and sands, making them subject to erosion. The flat, wide valley area consists of sandy soils. The land in this part of the basin is used for woodland and pasture in the higher elevation, while a significant portion of the valley is cultivated for cotton production.

Description of the Study Area

2. The study area, shown in Figure 2, includes Abiaca Creek from Highway 49E (Station 75+88) upstream to Station 948+49, a distance of about 15.4 miles, and Coila Creek from its confluence with Abiaca Creek to Station 193+92, a distance of about 3.6 miles. Abiaca Creek from the hill line (approximately Station 365+00) downstream to Station 75+88 has an existing levee system as shown in Figure 3.

3. Typical cross sections showing the channel and existing levees are shown in Figure 4. The cross-sections used in the study reach are identical to those used in the Vicksburg District UNET study (Little, 1991).

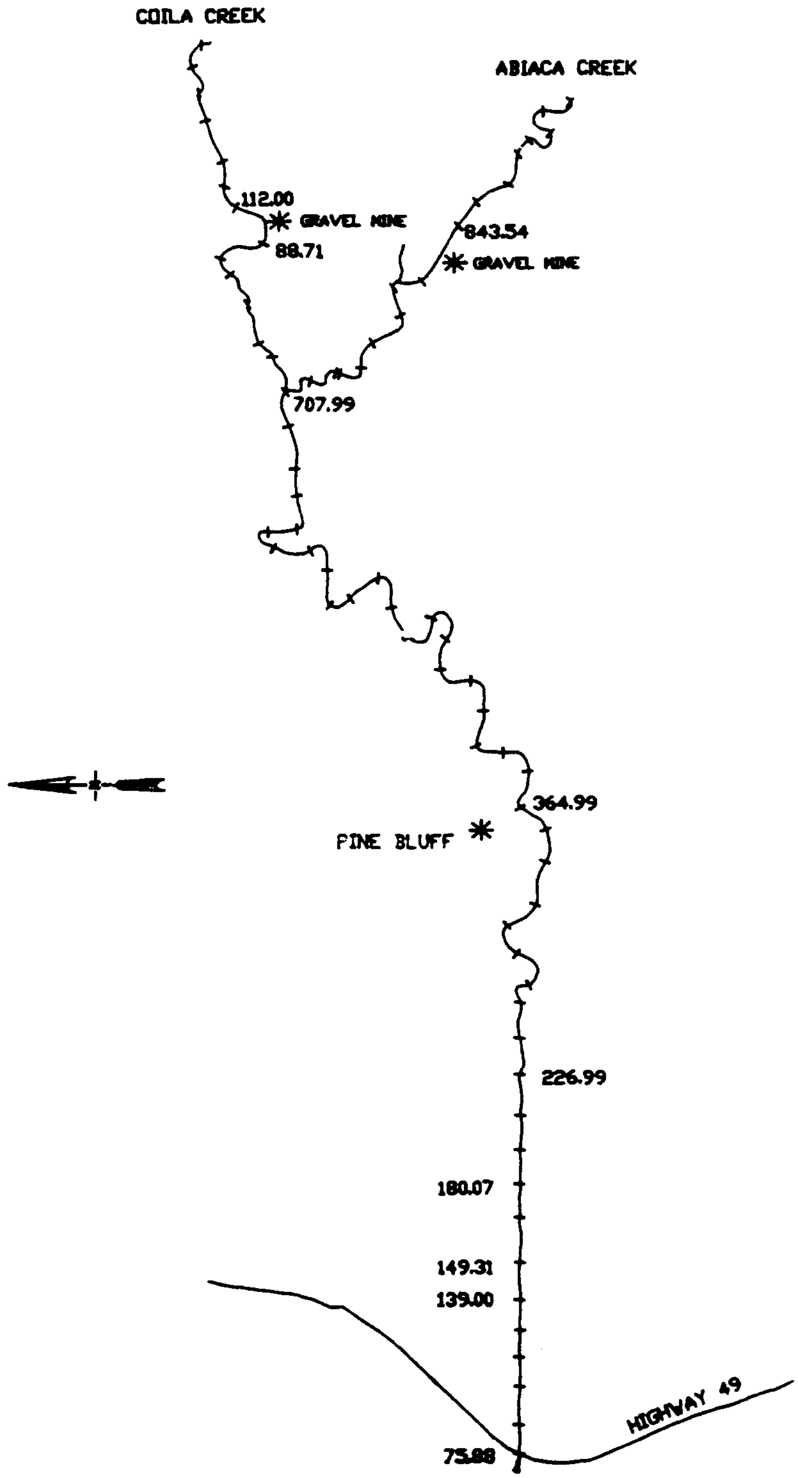


Figure 2. Abiaca Creek study area

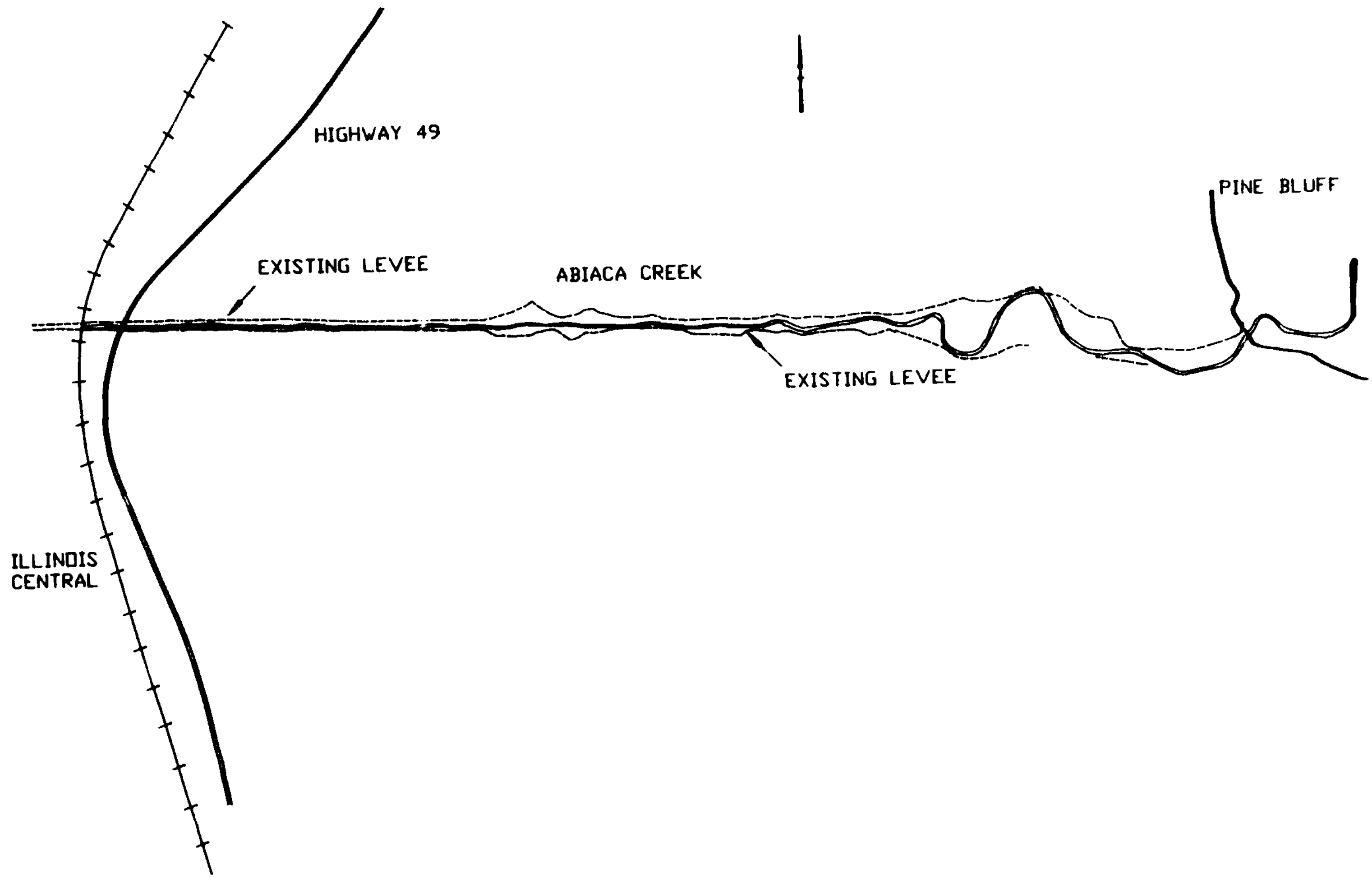
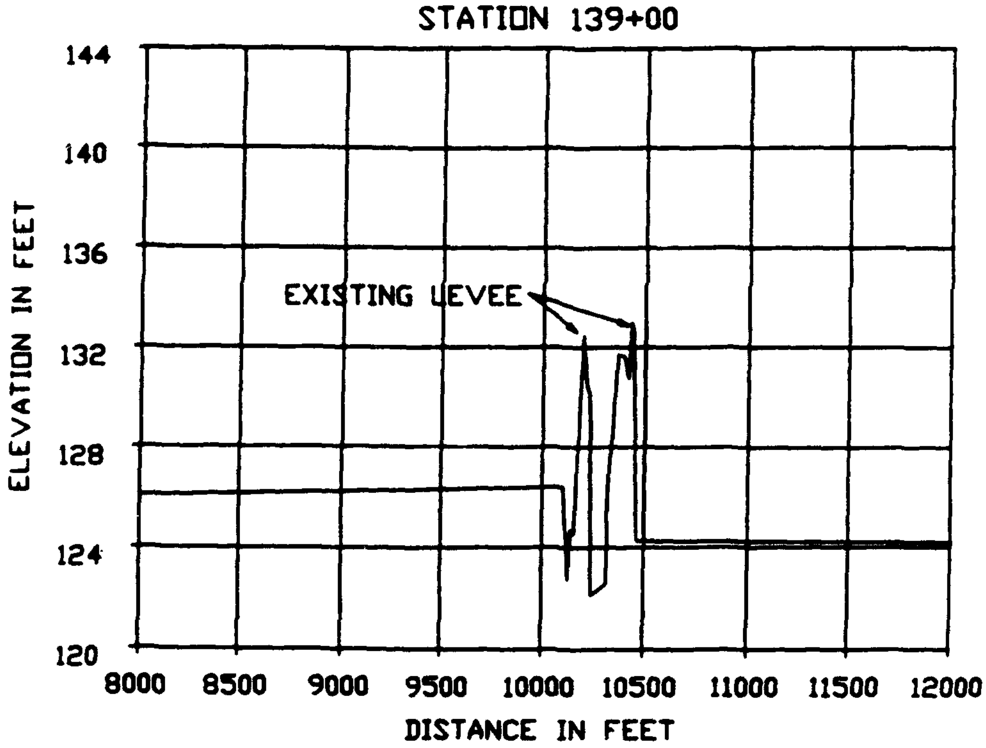


Figure 3. Abiaca Creek existing levee system



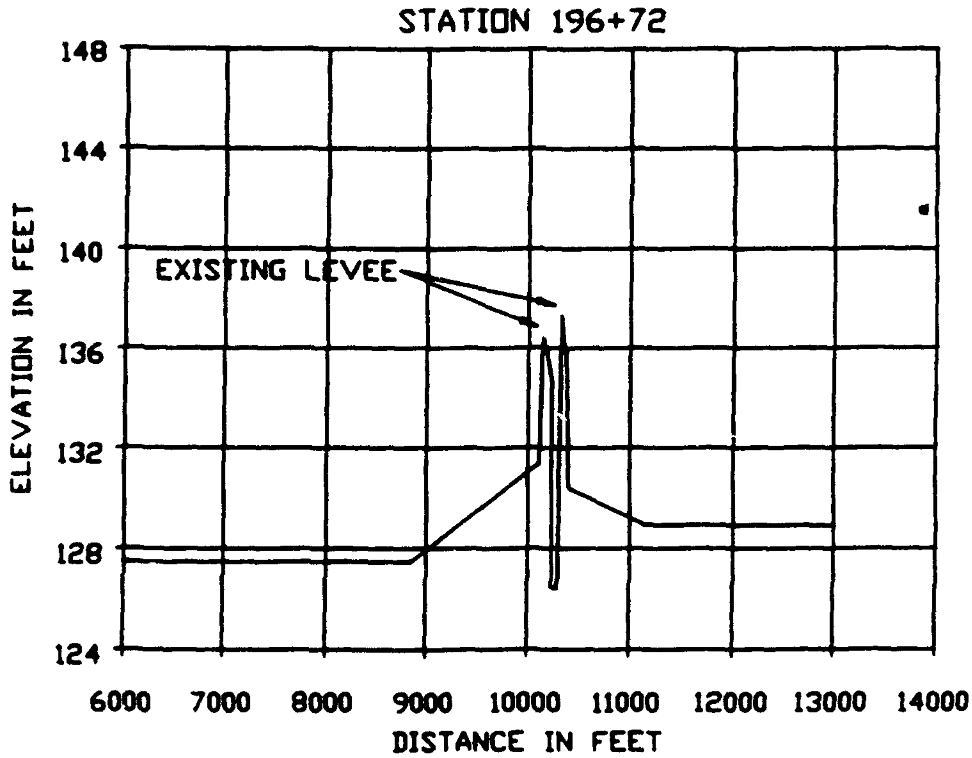


Figure 4. Typical cross sections - existing condition

Plan Description

4. The plan tested in this study consists of a flood-control levee system as shown in Figure 5. The plan also includes a lateral overflow weir, located at Station 149+31 (Figure 5). The lateral weir is designed to divert a portion of the channel flow from Abiaca Creek into a leveed overland floodway. The threshold flow for diversion is about 1800 cfs, i.e., at flows below 1800 cfs no diversion takes place.

5. Typical cross-sections showing the channel, the existing levees, and the proposed levees are shown in Figure 6. The Plan cross-sections used in the study reach are identical to those used in the Vicksburg District UNET study (Little, 1991).

Purpose and Approach

6. The purpose of the sedimentation analysis is to determine the effectiveness of the proposed Abiaca Creek sediment reduction scheme under both existing and plan levee conditions. The sediment reduction scheme consists of controlling the release of sand tailings from the gravel mining operations on Abiaca and Coila Creeks (Figure 2). To perform the analysis, the one-dimensional, numerical sedimentation model (TABS-1) was applied. The model was used to reproduce historical flow and sedimentation patterns for Abiaca Creek and, after satisfactory reproduction of the existing flow-sediment regime was accomplished, to determine the impact of the proposed levee and gravel mining modifications to Abiaca Creek sedimentation. The model was also used to assess change in sand delivery to the Matthews Brake wetlands area under plan conditions.

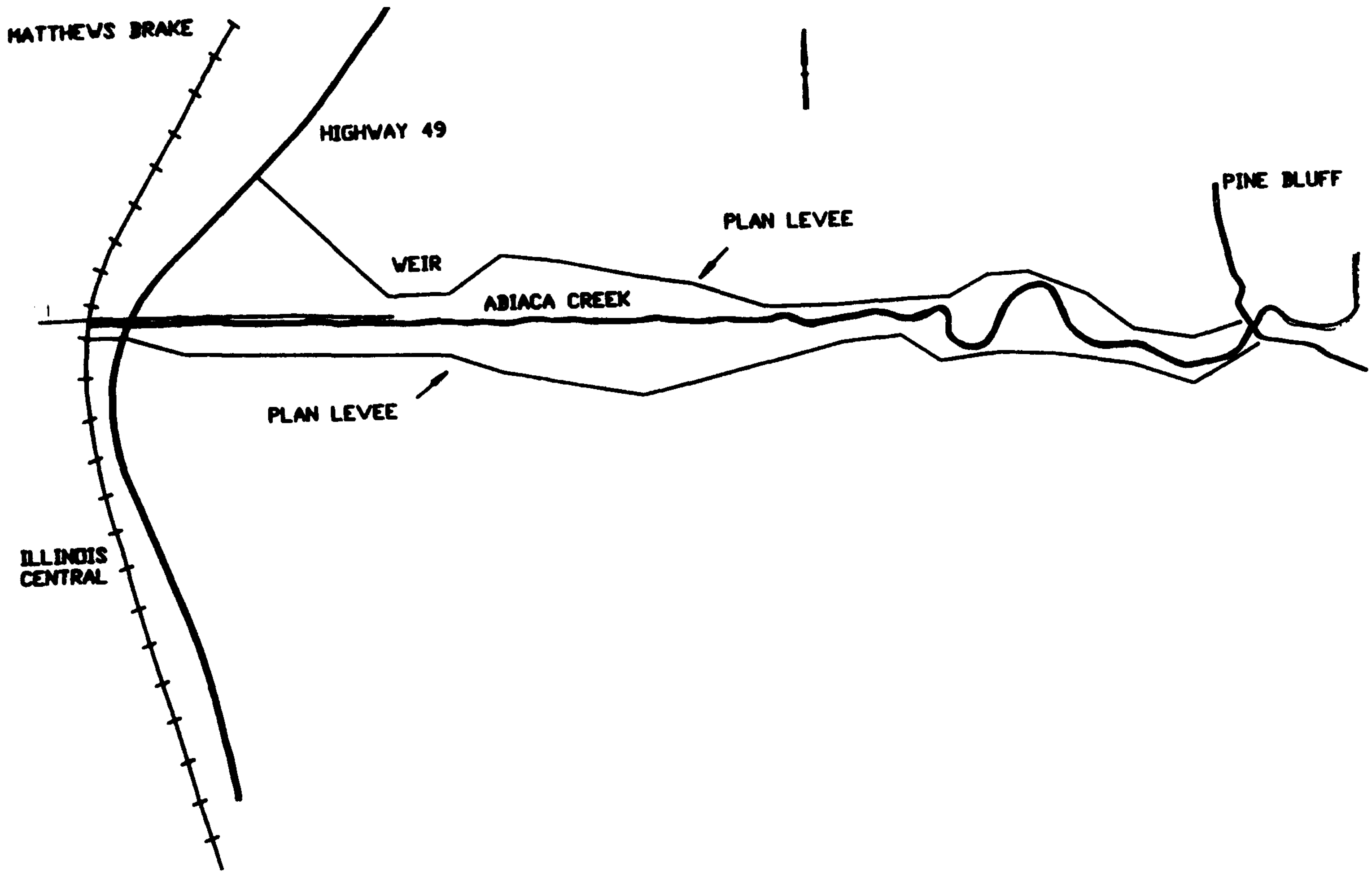


Figure 5. Abiaca Creek levee system - plan condition

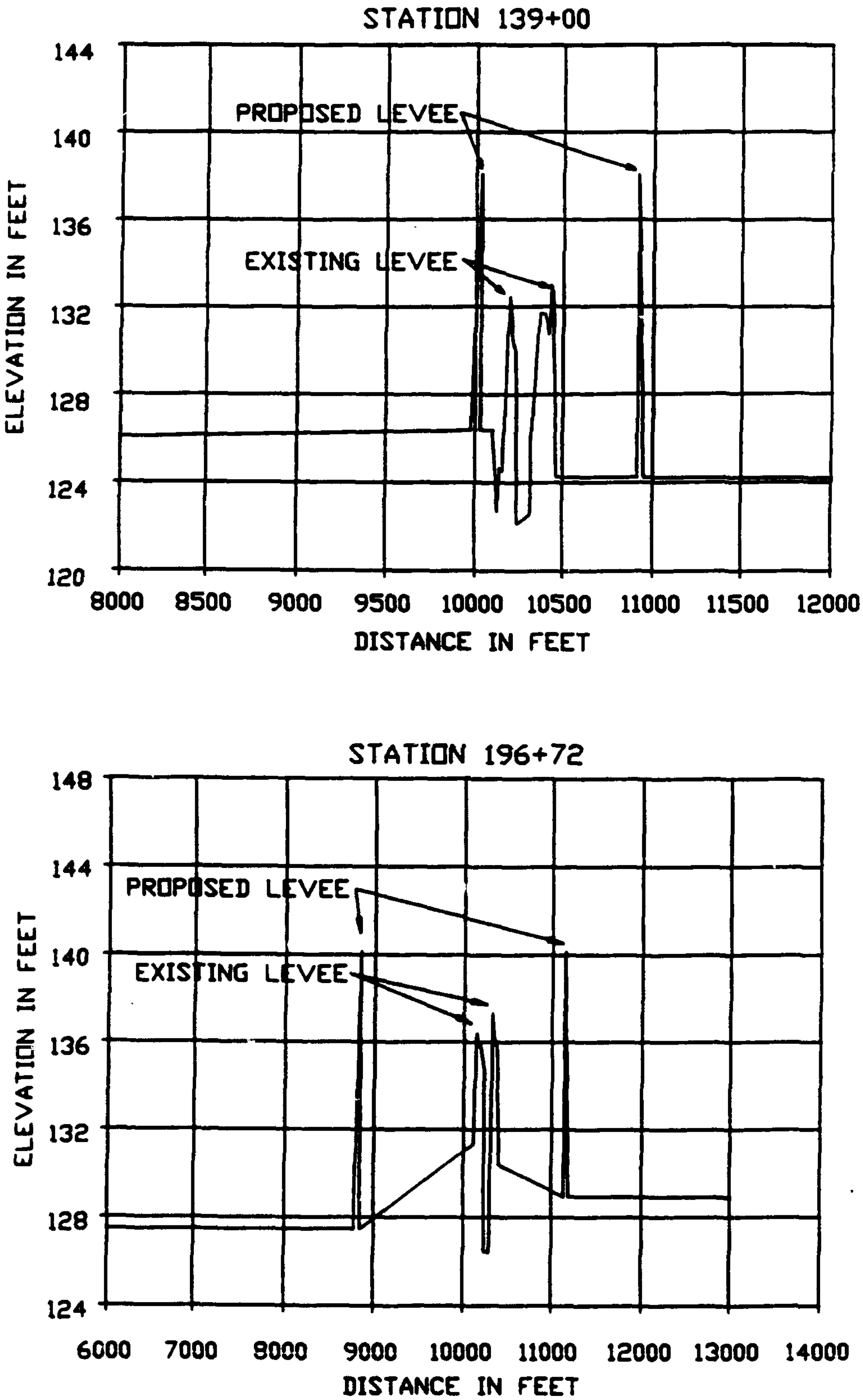


Figure 6. Typical cross sections - plan conditions

PART II: THE MODEL

7. The TABS-1 one-dimensional sedimentation program was used to develop the numerical model for this study. Development of this computer program was initiated by Mr. William Thomas at the US Army Engineer District, Little Rock, in 1967. Further development at the US Army Engineer Hydrologic Engineering Center (USAEHEC) by Mr. Thomas produced the widely used HEC-6 generalized computer program for calculating scour and deposition in rivers and reservoirs (USAEHEC 1991). Additional modification and enhancement to the basic program by Mr. Thomas at the US Army Engineer Waterways Experiment Station (WES) led to the TABS-1 program currently in use. TABS-1 is considered to be experimental in that it is not documented to the point that it can be made available for general use, but can be made available by special request. The program produces a one-dimensional model that simulates a series of steady-state discharge events and their effect on the sediment transport capacity at cross-sections and the resulting degradation or aggradation.

PART III: MODEL ADJUSTMENT

8. Most of the data available for model adjustment came from two previous studies done by Water Engineering Technologies, Inc (WET 1989, 1990) and a third study by Nathan D. Maier (1988). The Maier study contained data on hydrology, hydraulics, and sedimentation for the Abiaca Creek watershed. The WET reports consisted of a morphological analysis and a sediment analysis of the watershed. Data obtained from the Vicksburg District included stream cross-sections and a HEC-2-SR model developed by WET covering the reach from Pine Bluff to the railway bridge west of US Highway 49E (Figure 3).

9. The WET and Maier studies provided good data for design storm flows in the two creeks (Abiaca and Coila), information on bed material gradation in the stream beds, and channel cross-section information. Data on stream response to individual events or to specific periods of time were lacking. The data did indicate a long term aggradational trend at the Pine Bluff gage and an aggradational trend in the Matthews Brake located downstream of the railroad and Highway 49E bridges.

Channel Geometry

10. The WET study included the development of the HEC-2-SR model for the entire area of interest on the Abiaca and Coila Creek watersheds. Unfortunately, only the section from Pine Bluff to the railroad bridge was available. Since only the downstream portion of the reach to be modeled by TABS-1 was available, it was necessary to construct that portion of the TABS-1 model from Pine Bluff to points above the gravel mines on Coila and Abiaca Creeks. In order to prevent errors in the data file, an entirely new TABS-1 model was constructed from cross-sections obtained from the WET study (1989).

11. The Abiaca Creek TABS-1 model was developed using surveyed channel cross-sections obtained by the Vicksburg District in 1988 during studies of the Abiaca and Coila Creek watersheds. Overbank data were obtained from 7.5-minute USGS topographic maps and then appended to the surveyed cross-section data.

Bed Gradation

12. The TABS-1 model used bed gradation obtained by WET (1989). The density of bed gradation data was satisfactory on the portion of the watershed included in the HEC-2-SR model available from the Vicksburg District, but the distance between bed sampling points above Pine Bluff was rather large. Major changes in gradation occurred between a number of the sampling points.

13. During model adjustment, it was necessary to modify the model bed gradation at the Highway 49E bridge such that no degradation could occur along that reach. Without that modification, the model indicated significant scour at the bridge. Given the stream channel geometry downstream of the bridge, which indicates long term aggadational trends, such scour was considered to be unrealistic.

14. Both Coila and Abiaca Creeks were assumed to be in equilibrium above the mines. Accordingly, sediment inflows at the upstream end of both creeks were adjusted to give as close to a stable channel as possible. During the adjustment process it became apparent that sediments in the very fine, fine and medium sand classes were being transported through the model in suspension with very little bed interaction. Sensitivity testing showed that when the inflowing concentrations of these three classes of sediment were increased by a factor of 100, the outflowing load also increased by about the same factor with no noticeable bed changes.

15. Suspended sediment sample data, consisting of seven samples collected at Highway 49E, and two samples collected at Pine Bluff were provided by the Vicksburg District. These samples were used as the basis for the adjustment of the inflowing very fine, fine, and medium sand loads introduced into the TABS-1 model. The model was adjusted such that calculated concentrations at Pine Bluff and Highway 49E matched the measured concentrations as closely as possible. Some sample variability was noted, which was probably due to seasonality and/or the storage and subsequent release of fine sediments during hydrologic cycling.

Transport Function

16. The transport function selected as most appropriate for this study is the Laurson-Madden Function. Model tests were made with several transport

functions and results reviewed for adequacy before the final selection was made. Transport functions tested included the Laursen-Madden, Yang, and Copeland-Laursen functions. The Laursen-Madden was selected as most suitable based on the stream and sediment characteristics.

Hydrology

Upstream boundaries

17. Hydrologic (stage) records were incomplete for most of the time that aggradation occurred at the Pine Bluff gage. The hydrologic (stage) data that are available were obtained from 8am daily observations at Pine Bluff. Because of the set schedule for gage observations and the flashy nature of events in the Abiaca Creek watershed, it is likely that some small events and most peaks have been missed by the limited stage observations at Pine Bluff. The hydrologic data have been adjusted by WET (1989) to account for short duration events that may have been missed between observations.

18. The hydrologic data used by WET (1989) consisted of flow at Pine Bluff for a 10-year period. The 10 year hydrograph was repeated 3 times in the WET (1989) study for a total simulation time of 30 years. The WET (1989) simulation was shortened by the removal of flows under 100 cfs, which resulted in a condensed simulation time of approximately 7 years (2620.5 days). The justification for removing flows under 100 cfs was based on observations by WET (1989) that little or no sediment transport occurred in the HEC-2-SR model for flows of 100 cfs or less.

Mines

19. The hydrologic inflow at the mine on Abiaca Creek was set equal to 17 percent of the total flow in Abiaca Creek upstream from the Coila Creek confluence. The inflow from the mine on Coila Creek was set at 11 percent of the total flow in Coila Creek. These percentages were used by WET in their investigation of the mines sedimentation impact (WET, 1989). Since these values represent the only estimates available, they were used in this TABS-1 study.

Sediment Inflow

Upstream boundaries

20. The HEC-2-SR model obtained from the District included suspended

sediment concentrations at the bluff line on Abiaca Creek. These concentrations were not observed values, but were calculated values from the HEC-2-SR model. In that modeling effort the two creeks were modeled independently, since HEC-2-SR cannot handle branching systems. In that study, the upper end of both Abiaca and Coila Creeks were used as sediment supply reaches, with no sediment input at the upstream boundaries. Also, the sediment inflows from the gravel mines on Abiaca and Coila Creeks were used as adjustment parameters. The mine inflows were adjusted to achieve the proper amount of aggradation/degradation downstream from the mines. The fact that the Abiaca Creek and Coila Creek models were uncoupled seems to have caused unrealistic scour in the Abiaca Creek model downstream of the Coila Creek confluence.

21. Since no measured sediment inflow data were available, a reach was modeled upstream of the mines on Abiaca and Coila Creeks that was long enough to allow model stabilization. The model was run for the same hydrologic simulation used by WET (1989), using zero sediment inflow from the mines and zero sediment inflow from the upper ends of Coila and Abiaca Creeks. The result was approximately 5 ft of scour at the upstream end of the model on Abiaca Creek. Scour at most cross-sections was less than 2 ft, and the model overall was extremely stable.

22. To further test channel stability, a 100-year event was simulated with no upstream sediment inflow. The result was again very little degradation of the channel along Abiaca Creek. Further sensitivity testing was conducted with different transport functions and all such tests indicated less than 5 ft of scour after the 30-year simulation, assuming bed samples are representative of actual bed material.

23. After the above sensitivity tests were completed, the inflowing sediment load was adjusted to be in approximate equilibrium with the transport capacity of the two streams. When scour at the upstream end of both creeks was less than 2 ft after the 30-year period, the sediment inflow was considered to be sufficiently in balance for study purposes. During these tests, it was observed that sediment in the very fine, fine, and medium sand classifications were transported through the model, not depositing in any significant quantity. This was true even when the total loading in these size classes was increased by one or even two orders of magnitude.

Mines

24. After adjustment of the inflowing sediment load, the problem of

approximating the sediment inflow from the two gravel mines was addressed.

25. Sediment inflow and gradation curves were not available for the gravel mine located on Abiaca Creek or the gravel mine located on Coila Creek (Figure 2). The only information available on sediment inflow from the mines was the WET (1989) estimate of 73,500 tons/year as the average annual contribution from the Abiaca Creek mine. This rate of sediment inflow was used by WET (1989) during the verification of the HEC-2-SR model.

26. The above Abiaca Creek mine sediment inflow rate was divided by a factor of 6 to estimate the sediment inflow from the Coila Creek mine, resulting in an average inflow from the Coila Creek mine of 12,500 tons/year. The factor of 6 represents the ratio of areas between the Abiaca Creek and Coila Creek mining operations. The manner in which sediment entered the creeks with respect to flow rates and grain size represented was not specified in the WET (1989) report.

27. The problem of estimating grain size for sediments entering at the mines was addressed by obtaining and analyzing two samples from the Abiaca Creek mine tailings. Based on site reconnaissance at the Abiaca Creek mine and aerial photography available from the Vicksburg District, the mine tailings appear to represent the majority of sediment entering Abiaca Creek from the mining operation, or at least the majority of sediment that could impact the stream channel prior to reaching Matthews Brake. The results from the sieve analysis of the two samples from the mine tailings adjacent to Abiaca Creek are shown in Figures 7 and 8.

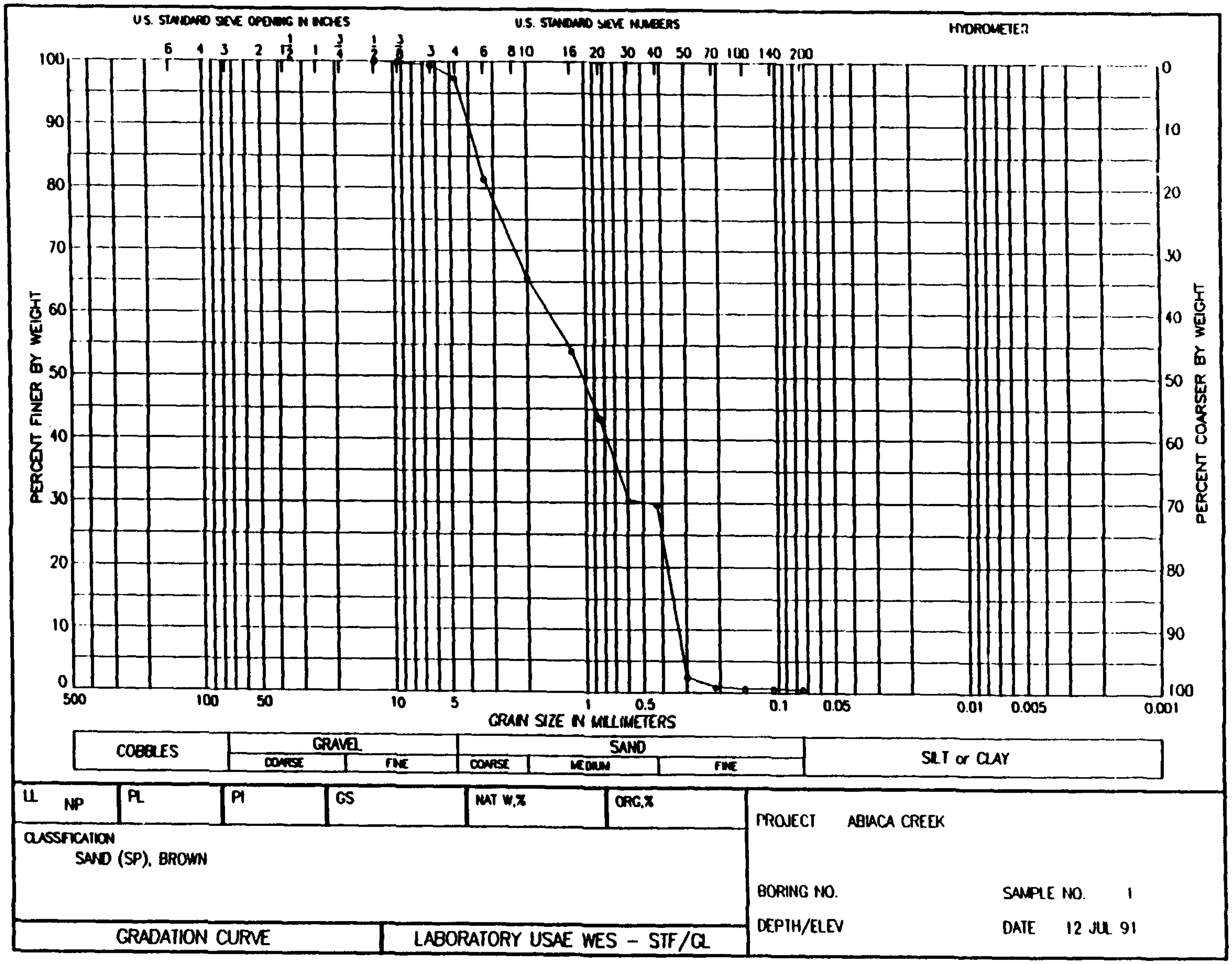


Figure 7. Gradation curve of mine tailings adjacent to Abiaca Creek - Sample No. 1

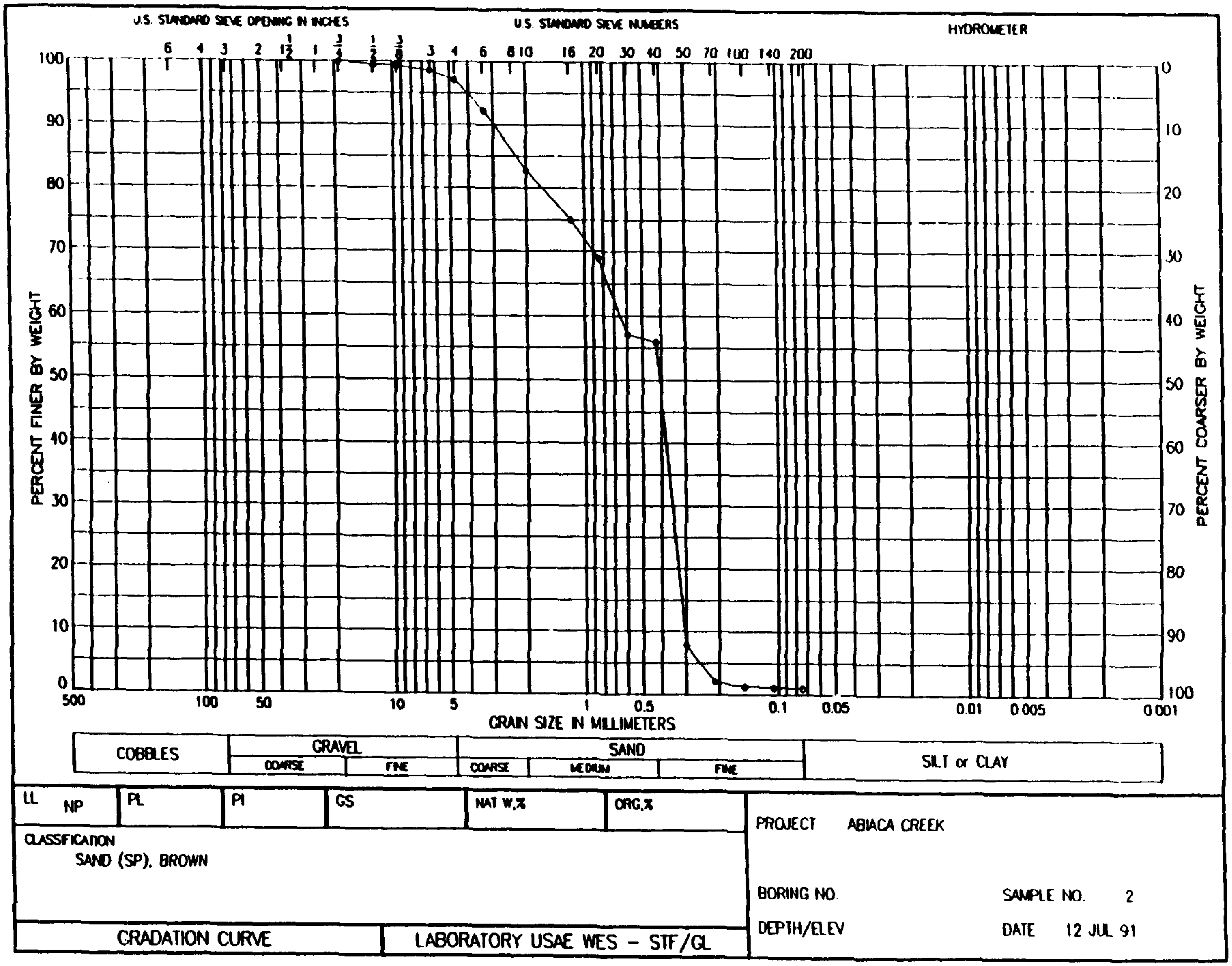


Figure 8. Gradation curve of mine tailings adjacent to Abiaca Creek - Sample No. 2

PART IV: MODEL RESULTS

Existing Condition Results

28. After three repetitions of the ten-year historical record, the resulting Abiaca Creek bed degradation profile is shown in Figure 9. As can be seen, the bed degraded a maximum of 2.9 ft at cross section 226+99. In the area of the Abiaca Creek mine, the bed degraded a maximum of 1.8 ft with the mine sediment controlled and aggraded 6.8 ft with the mine sediment uncontrolled. Near the Coila Creek mine, the degradation was 3.5 ft with the mine sediment controlled and 2.4 ft with the mine sediment uncontrolled.

29. The 6.8 ft of aggradation downstream of the mine on Abiaca Creek was felt to be high, given the long period of mine operation and the existing creek profile (Figure 10). A slight change in slope can be noted in the existing profile upstream and downstream of the mine indicating some aggradation in the area of the mine. The base test with mine sediment uncontrolled, base with mine sediment controlled off, and the existing profile for the area near the mines (Station 843) are shown in Figure 11. The downstream slope was extended through the area of the mines (as shown by the line without markers in Figure 11) and shows about 2.5 ft of aggradation in the immediate area of the mine. The base test with mine sediment uncontrolled shows the bed returning to near the bed predicted by the downstream slope.

30. The aggradation and degradation near the mines was found to be very sensitive to the loading patterns used to input the sediment into the streams. Varying the loading curve varied deposition at the mines from near zero to unrealistic depths. The loading curve used consisted of very low sediment inflow during in channel flows and very high loads when the creeks were in flood stage and in direct contact with mine tailings. In the case of the mine on Abiaca Creek, flood flows undercut the toe of the tailings pile and produce bank failures in the tailings pile. A slope failure would introduce massive amounts of sediment into the creek. It was noted that most of the sediment introduced from the mines in the TABS-1 model was deposited within about 1 mile of the mines and bed elevation differences were small at distances in excess of about 2.0 miles.

31. Since the aggradation depth was found to be extremely sensitive to the sediment loading pattern at the mine, and given that the sediment inflow

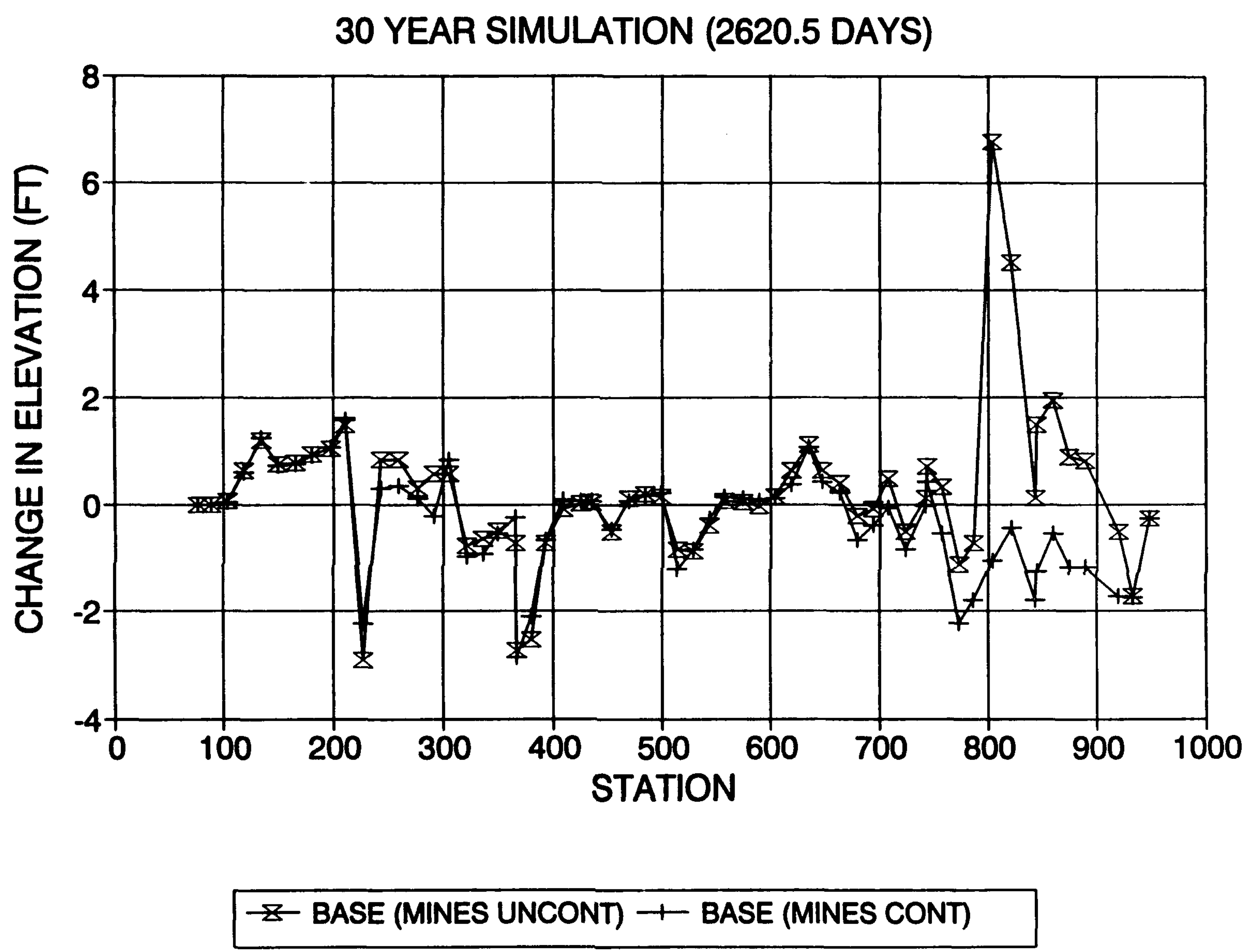


Figure 9. Abiaca Creek bed degradation profile for existing condition

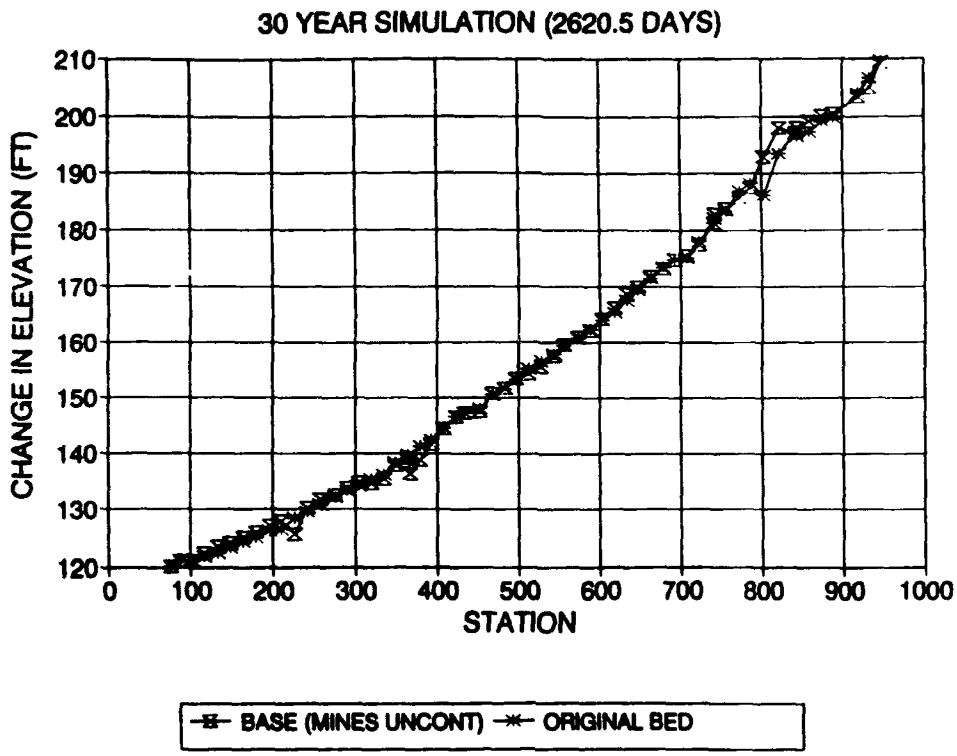


Figure 10. Abiaca Creek bed profiles

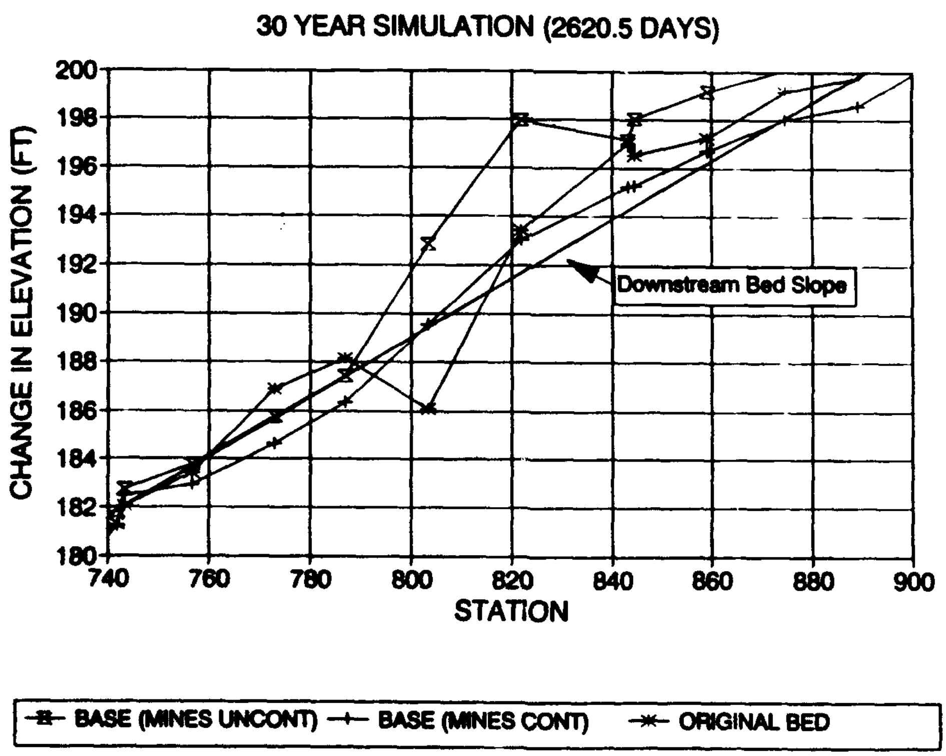


Figure 11. Bed profiles in vicinity of Abiaca Creek mine

at the mine is estimated from the WET (1989) model with no field data for support, it is felt that the total degradation which can be expected as a result of the control of sediment inflow at the mines is about 3 ft. In order to develop more exact estimates of aggradation and degradation at the mines the estimates of the actual sediment loading patterns and amounts need to be obtained.

32. The simulation with the 6.8 ft of aggradation was used for the base run since it is apparent that the stream is overloaded with sediment at the mines but not so seriously as to give unrealistic results. The sediment is also carrying downstream from the mine one to two cross sections which indicates that the loading, while high, is being transported during the high flow events. This should introduce near the maximum amount of sediment the creek can carry downstream of the mine. Even with this high loading there is little difference between the two profiles downstream of station 750 as shown in Figure 9.

33. Sediment delivery to the downstream end of the model averaged 13022 tons per year of sand and gravel with sediment delivery at the mines controlled. This is 18.7 percent of the estimate by WET (1989). The WET (1989) estimate of sediment delivery to Matthews Brake was based on measured aggradation in the Brake over a period of 11 years. The entire aggradation was assumed to be due to sand delivery which does not appear to be a valid assumption. The nine suspended sediment samples, consisting of clay, silt, and sand mixtures, show sand content ranging from 2 to 24 percent of the total sample. Thus the concentration of sediments in the silt and clay sizes is significantly higher than the sand concentrations. The very fine sand, and fine sand fractions of the sediment load do not deposit in the Abiaca Creek model prior to reaching Matthews Brake. The silt and clay sizes were not modeled. The silt and clay size classes appear to account for a sizable portion of the aggradation in Matthews Brake.

34. The average amount of sediment delivered to Matthews Brake with the mine sediment uncontrolled was 17317 tons per year, or 24.9 percent of the WET (1989) estimate. Based on the estimated loading patterns and inflowing sediment load, the mines account for about 24.8 percent of the sand transported into Matthews Brake or 6.2 percent of the WET (1989) estimate for total deposition in Matthews Brake.

35. Both of the above sediment delivery estimates are within the range

of scatter of the observed ratios of sand-to-finer concentrations. The calculated size distribution curves were in agreement with the very fine and fine sand size classifications for the nine suspended sediment samples that were provided by the Vicksburg District for comparison.

Plan Results

36. To conduct plan tests that took into consideration the attenuation of peak discharges noted from the Vicksburg District UNET model (Little, 1991), flow adjustments were made in the TABS-1 model. Three points on the lower end of Abiaca Creek were selected for flow adjustment. The three locations are Station 364+99, 180+07, and 139+00. These cross sections are located downstream of channel reaches that contained significant amounts of overbank storage during flood events. The effect of such overbank storage is to decrease the downstream peak discharge.

37. The dynamic hydrographs provided from the Vicksburg District UNET results (Little, 1991) are shown in Figure 12. The discharges used in the TABS-1 model were adjusted to reflect the flow attenuation indicated by the UNET curves based on a linear interpolation of the two-, five-, and ten-year flood events. The reduction in peak discharge at the selected adjustment points, as determined from UNET, was used to develop a relationship that reduced the discharge proportionally in the TABS-1 model. The resulting equations are as follow:

$$Q365 = QT-(QT*0.19-1100)$$
$$Q180 = Q365-(QT*0.28-1000)$$
$$Q139 = QW-(QT*0.40-800)$$

where QT = total discharge in cfs

Q365 = discharge in cfs at cross-section 364+99

Q180 = discharge in cfs at cross-section 180+07

Q139 = discharge in cfs at cross-section 139+00

QW = discharge in cfs at the cross-section 149+31 (weir)

38. The Weir Discharges, QW, was calculated from information provided by the Vicksburg District (Little, 1991). A rating curve (Figure 13) was developed from the UNET model results so that flow diversion at the weir

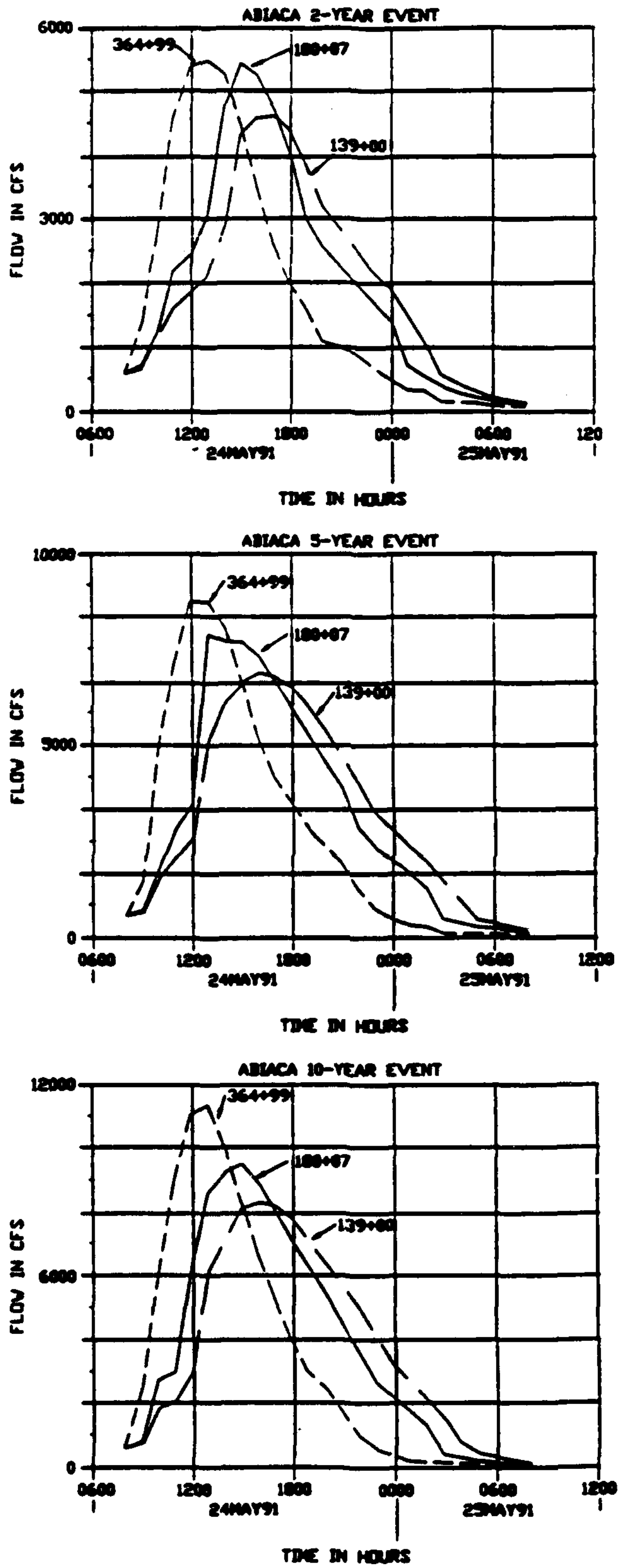


Figure 12. Peak discharge attenuation along lower Abiaca Creek (calculated by UNET)

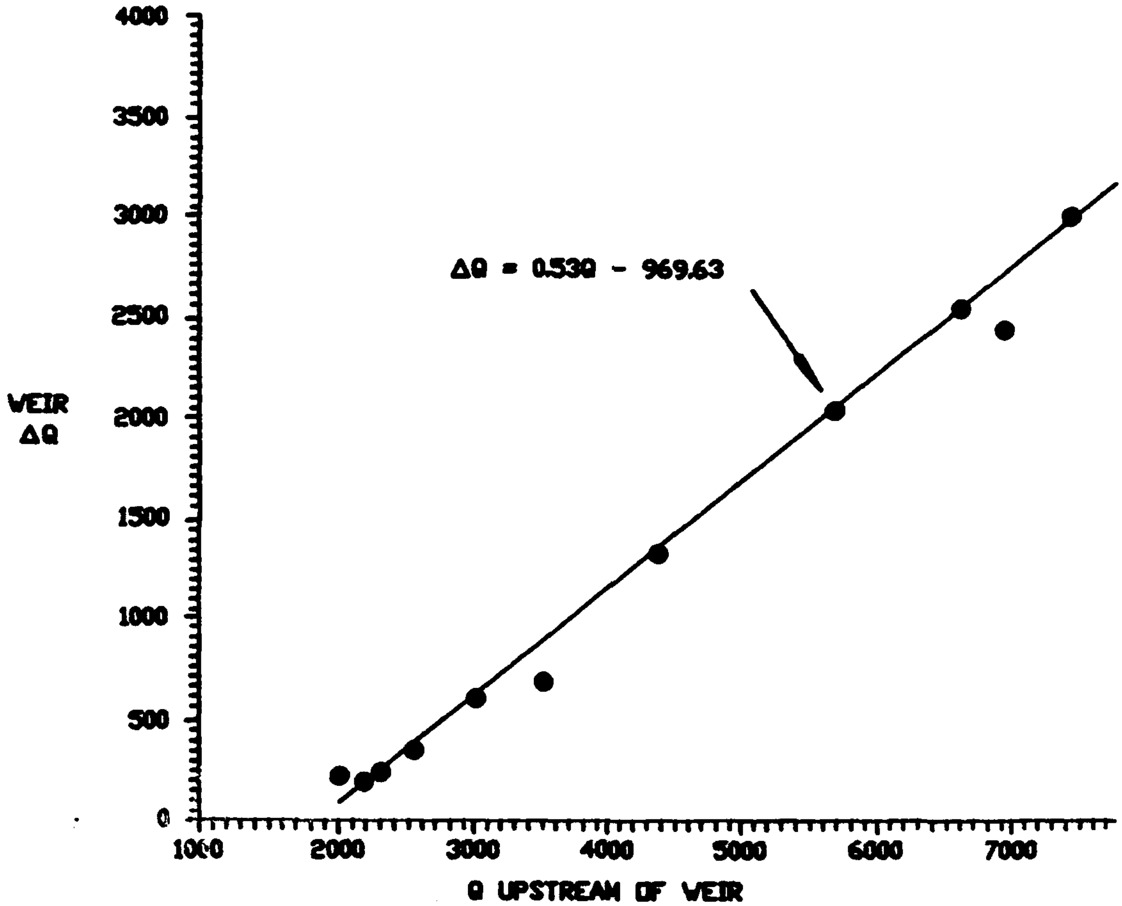


Figure 13. Weir discharge rating curve

location could be specified in the TABS-1 model. As can be seen from Figure 13, the threshold discharge for diversion is about 1800 cfs.

39. After three repetitions of the ten-year historical record, the resulting Abiaca Creek bed degradation profile with mine sediment controlled is shown in Figure 14. Compared to the existing condition profile (Figure 9), deposition occurs under plan conditions between cross sections 320+29 and 434+49. This is due, in part, to the attenuation of flow at cross section 364+99. Less deposition is noted between cross sections 164+61 and 210+49 probably due to the increased deposition near Pine Bluff. Most other areas of the plan are very similar to the base condition tests.

40. Sediment delivery (sand) to Matthews Brake was equal to 3863 tons per year. This is a 77.5 percent reduction in sediment delivery compared to the base condition with the mines sediment uncontrolled.

41. Results on Coila Creek show maximum scour with no sediment inflow

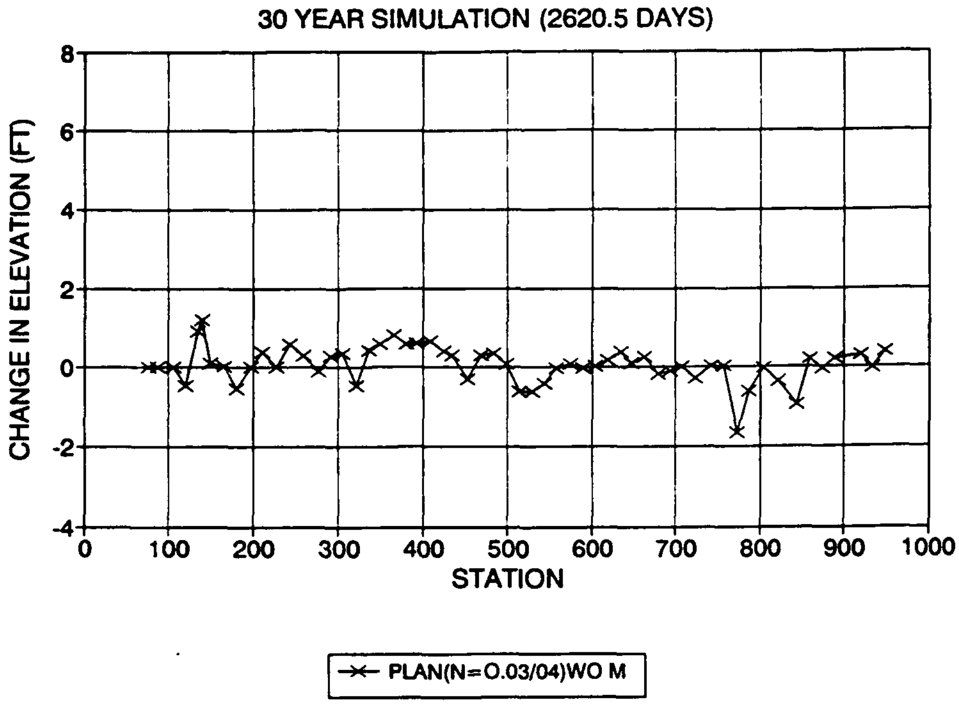


Figure 14. Abiaca Creek bed degradation profile for plan condition (mines controlled)

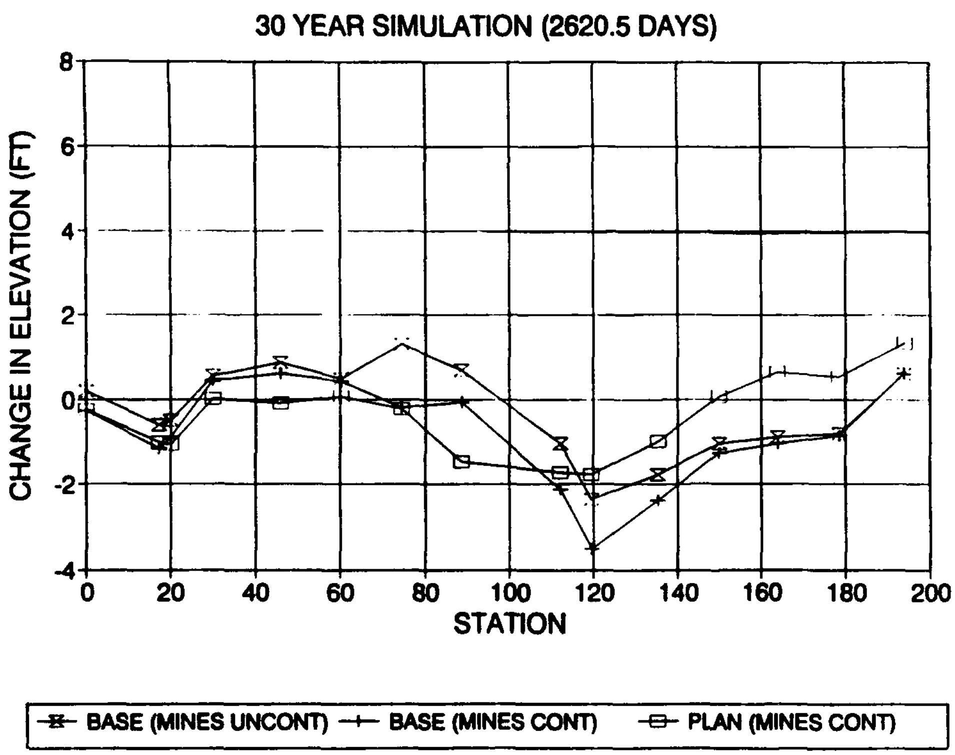


Figure 15. Coila Creek bed change profile for base (mines uncontrolled and mines controlled) and plan (mines controlled) conditions

from the mines to be 3.5 ft for the base condition and 1.8 ft for the plan (Figure 15). No differences exist between models for the base and plan tests on Coila Creek. It appears that the sediment inflow from the Coila Creek mine is greater than 16.7 percent of the Abiaca Creek mine outflow if Coila creek is currently assumed to be stable or aggrading.

PART V: CONCLUSIONS AND RECOMMENDATIONS

42. Based on the model testing conducted in this study, the following conclusions are made.

a. Under plan conditions (with the gravel mines sediment controlled), the TABS-1 model tests did not predict any severe aggradational or degradational problems along Abiaca or Coila Creeks. Maximum degradation over the 30-year simulation was less than 2 ft on both Abiaca and Coila Creeks. Maximum aggradation was slightly over 1 ft on both Abiaca and Coila Creeks.

b. The TABS-1 model predicted significant aggradation on Abiaca Creek in the reach downstream of the gravel mine under existing conditions. The model predicted about 7 ft of aggradation but given the long period of mine operation, the existing bed profile, and the sensitivity of the model to mine loading patterns, it is estimated that actual aggradation at the mines during a 30 year period should be about 2 to 3 ft. With the mine sediment controlled the same reach degraded from 0.5 to 2.0 ft and approximated the profile estimated by extending the downstream bed slope through the mine area.

c. Sand delivery to Matthews Brake was significantly reduced under the plan condition. Over the 30-year period, plan sediment delivery to Matthews Brake was only 22.5 percent of that for the existing condition.

43. It should be noted that the model bed was based on limited bed sediment data. These data indicated sufficient gravel content to allow bed armoring, resulting in limited degradational trends. It is recommended that more detailed collection and analysis of bed sediments along Abiaca and Coila Creeks be conducted to confirm that gravel is available in sufficient quantity for bed armoring to occur. Suspended sediment samples should also be obtained both upstream and downstream of the mines for a range of events such that sediment inflow and loading patterns from the mines can be better estimated.

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